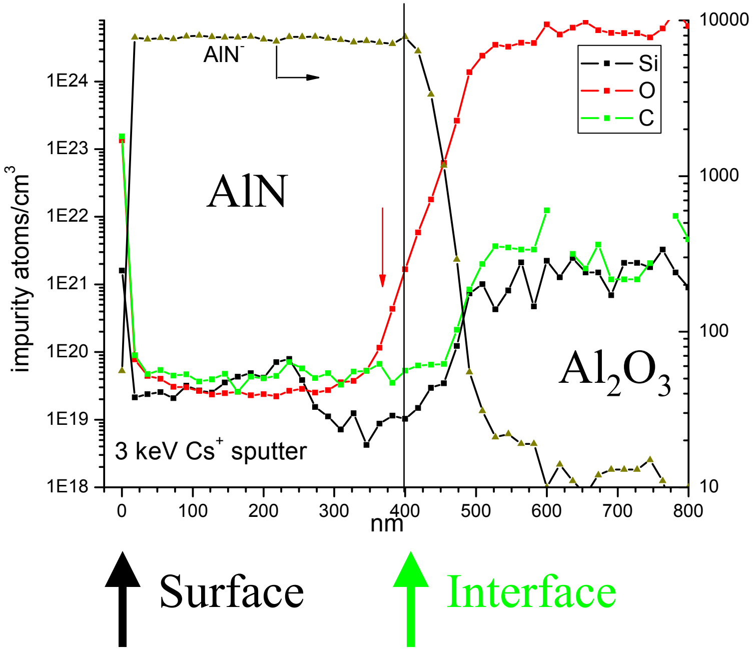
Ohio State University's Secondary Ion Mass Spectrometry and Cathodoluminescence Spectroscopy

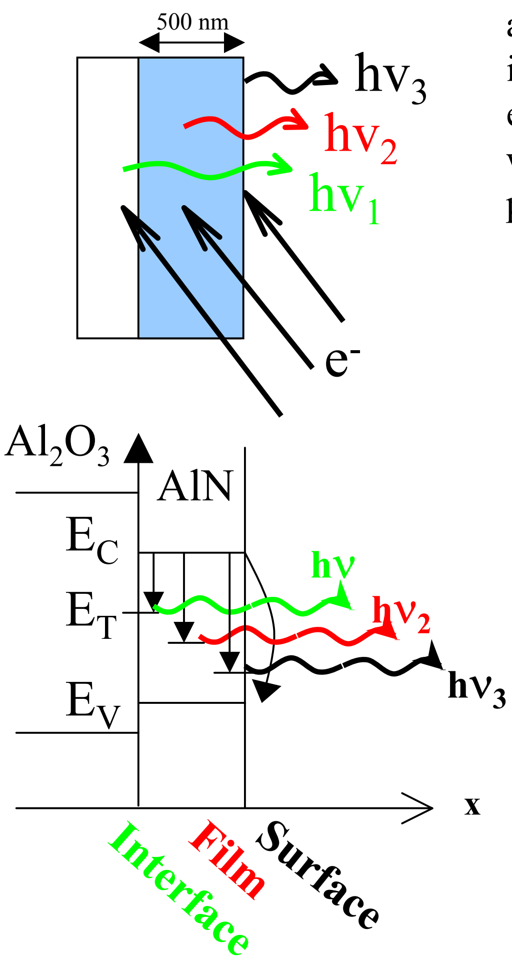
A new tool for interface electronic analysis. The successful introduction of charge donors or acceptors is fundamental to the creation of modern electronics, yet it requires control of atomic composition to levels of parts per million or less. Secondary ion mass spectrometry (SIMS) is a powerful tool to probe atomic composition on this level, yet until now it has not been correlated spatially with the electronic activity of the constituent species. Such correlations can reveal which combination of atoms contributes to the free charge in a semiconductor and what microscopic chemical processes, e.g., diffusion or chemical reaction, are responsible for their spatial distribution. In the case of ultra-wide band gap semiconductors such as AlN, Ohio State's combined analysis enables researchers to refine their growth processes in creating, for instance, two-dimensional electron gas channels, light emitting diodes, UV lasers, and solar-blind detectors.



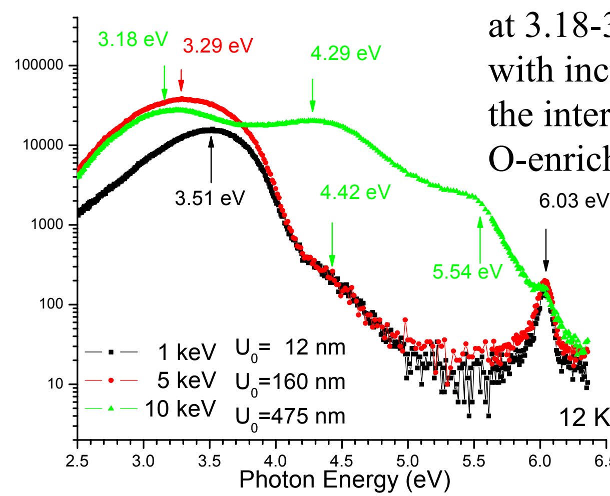
A SIMS depth profile of a 500 nm AlN film on its Al_2O_3 growth substrate. The O profile extends over 150 nm into the AlN, revealing O diffusion out of the substrate. Depth-dependent cathodoluminescence spectra obtained selectively from the free AlN surface, the AlN bulk, and the AlN-sapphire interface reveal optical transitions corresponding to deep electronic levels that can be identified with the outdiffusing O as well as C. Removal of these deep levels will increase carrier concentrations and enable active optoelectronics in the UV.

Ohio State University's Secondary Ion Mass Spectrometry and Cathodoluminescence Spectroscopy

The energies and physical origins of deep levels in many semiconductors such as AlN are relatively unexplored. Depth-resolved luminescence spectroscopy combined with SIMS depth profiles show how these deep levels vary with alloy and impurity concentrations. Correlations between optical properties observed with luminescence spectroscopy and impurity concentrations from SIMS provide a physical basis for understanding the dopant and deep level properties of high-Al content AlGaN.



Incident electrons with keV-range energies produce cascades of secondaries and electron-hole pairs that peak at depths U_0 on a nanometer scale that increase with increasing energy. The resulting electrons and holes recombine either across the semiconductor band gap or via deep levels in the band gap with characteristic energies hν. By increasing the incident energy, one can probe at the free surface, the "bulk", or a "buried" interface of the thin film.



Spectral features show the near band gap emission of AlN at 6.03 eV, O deep levels at 3.18-3.51 eV whose energies decrease with increasing O content and proximity to the interface with Al_2O_3 - as expected for an O-enriched interface. Additional deep levels appear at the interface.

Removal of these deep levels during growth or in subsequent diffusion will increase free carrier concentrations and enable active optoelectronics in the UV.